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## POST-GRADUATE STUDY IN APPLIED CHEMISTRY

THE subject assigned to me in this discussion seems to have been somewhat mixed. I have been asked to discuss:

1. To what extent is post-graduate training recognized or desired by employers of chemists?

2. What should be the attitude of technical interests toward post-graduate work?

3. What should be the attitude of technical institutions toward post-graduate study?

It matters little how the subject of our discussion is stated, it really becomes, What shall be the training or education of young men whose life work shall be the applications of chemistry, or physics, or both, in the industries? It is a question which the experience of a century at least has scarcely solved. The elements which enter into the answer are too varied, the results to be attained too manifold, the conditions available too perplexing, the personal equation too persistent. Shall the training be confined to the storage of the facts and laws of chemistry and physics in the minds and memories of the young students, trusting to the exigencies which may arise to find their application, and that when the exigencies do arise the facts and laws will be brought forth and be wisely applied? Or shall we first cause storage of facts, principles and laws, and afterwards offer training in the methods whereby these shall be applied and employed in the solution of the problems likely to arise in the industries and to demand treatment with satisfactory results?

Whatever may be said, the latter is what employers expect and demand. The questions which arise must be answered promptly and accurately. The amount of knowledge a man may have acquired and may possess is little appreciated unless it can be applied usefully and effectively. Complaint is not uncommon that young men from the technical schools are over-educated, overtrained; educated above and beyond the positions they must occupy and the work they have to do. While this is unfortunate in form of statement, it nevertheless expresses a fact. Many young men are profoundly educated in theories and laws and at the same time acquire little or no appreciation of the practical value of these theories and laws, even in the advancement of the science to which they relate, and certainly not in the solution of the problems of the industries and the arts of life. There is therefore, whether recognized or not, a demand for something beyond the regular course of study of the university or the technical school. Something beyond the mere cramming with facts and the academic training, to the exclusion of the systematic utilization of knowledge in the promotion of knowledge. Here then is the problem propounded to the educator for solution: How shall young men be educated and trained to meet the demands likely to be presented to them by the chemical industries? In the chemical industries it is natural that a profound knowledge of chemical laws should be required, but in addition to this there must be provided a sound knowledge of such laws of physics as may be necessary to the physical application of chemical laws. In the undergraduate school, first the laws of chemical action and the properties of matter, theoretical and descriptive chemistry, the methods of chemical analysis, qualitative and quantitative, must be taught, and it is well known that one of the first steps in laboratory instruction in these methods is an introduction to the forms of apparatus to be employed in the practise of experiment and analysis. Then comes the application of the laws of chemistry and of the properties of matter to the methods of operation to be used. Now since manufacturing or industrial chemistry is really analytical chemistry in a large way, similar lines of instruction and training must apply in preparation for the industries. If acquaintance with the beaker, the casserole, the filter, the evaporating dish, the distilling apparatus, must be provided in the analytical and research laboratory; if here must be taught the sources and mode of application of heat; transfer of liquids, separation of vapors, liquids and solids; so all these processes made in a small way in the laboratories must be made large in the works. Operations made in a large way must be studied, and the means for effecting them made familiar. The operation of the chemist in the laboratory must become the operation of the engineer in the works. The industries demand that the men who shall control shall have some of that capacity known as engineering, shall know something of the materials and methods of engineering, of the larger apparatus to be employed and its management, and ability to apply the laws of physics in the larger operations of the works. Chemistry and engineering must, therefore, be combined in some measure at least, in the training of the men who will become most successful in meeting the demands of the "technical interests," and whether this is recognized generally or not, it is certainly desired by employers of educated chemists.

But the common complaint of the institutions and their teachers is, that the customary four years allotted to the undergraduate course is too brief for all

that is demanded and required. Here, then, is the problem to be solved: What shall be provided in the undergraduate course or school, and shall post-graduate study and training be provided and carried on under the direction and management of the educational institution, or shall the training, which might be provided by post-graduate study, be deferred and be supplied by actual practise in the works? How, and by whom, shall this very important question be answered? The demand of the present, and of the immediate future, is for men who are able to work independently, to take care of the problems arising, and work them out to successful issue, with profitable result. Directors in the industries and employers have little time, energy or freedom from detail, to devote to the training of young men in fundamental principles. Yet experience can be had only in practise, and this must be paid for in the time, energy and material apparently wasted by young men in the earlier periods of their life work.

But the question still persists. Could the young man working under intelligent direction in the systematic application of the principles he has been taught save time? Will the work of one, two or three years under intelligent and patient training of competent teachers save time of the young man and his employers and relieve both of embarrassment, loss and disappointment?

The laudation of the German chemical industry has extended to all nations, and is probably justified. In some of the most successful branches of the German chemical industry the practise is to take into the works only men who have served as *Privatdocent* in university or technical schools, and to become *Privatdocent* the candidate must generally have taken a course in post-graduate work in investigation and in the solution of problems; work leading to the doctor's degree. First, a training for systematic applied work, then experience in teaching. The value of the latter in the preparation of young men for life work is, I believe, too little recognized. It is certainly true that one of the most excellent means of securing a thorough and fundamental knowledge of a subject is found in an effort to impart such knowledge to others.

I have said elsewhere that an important adjunct to the successful application of knowledge is a trained imagination. Not an imagination "like the baseless fabric of a vision," nor "such stuff as dreams are made on," but an imagination based upon knowledge which furnishes a vision of what may be accomplished and suggests means for accomplishment.

So it seems to me that the proper function of the undergraduate school is to communicate knowledge of facts and methods and that the function of the post-graduate school is to furnish training in the application of knowledge to the solution of problems, to the training of the imagination, and thus to meet the demands which the industries, consciously or not, are making.

A most useful beginning in such work has been made in the laboratories for research in industrial chemistry lately established in some of the leading technical institutions. Here the subjects for research, the applications of knowledge, are not of an abstract but of a concrete character, and provide training in work which may produce results immediately useful in the arts of life. Here the problems arising in the industries in every-day work are solved by students, under direction of men who have themselves been trained in the solution of such problems. By such work the imagination is stimulated and at the same time trained and directed in proper channels; habits of application es-

tablished which must be fruitful later on. The designers of these laboratories, and the authorities who have ordered their organization and establishment, as well as the industries which have patronized and encouraged them, all deserve the highest praise. It is a step in the right direction, and one which must be taken in other educational institutions, if the proper and most effective training of young men for the industries is to be secured.

What then should be the attitude of the industries to post-graduate work? I answer unhesitatingly—*favorable.* What should be the attitude of the technical institutions to post-graduate work? I answer without hesitation, *favorable.* Post-graduate work should be earnestly encouraged from both sides, from the educational and from the industrial, and particularly from the latter. It has been fully recognized in the German institutions by providing in the technical schools courses leading to the degree of "doctor of engineering," and in the universities by the establishment of similar courses and providing for the same degrees. In all educational institutions the attainment of the degree of doctor—a degree not lightly appreciated nor glibly assumed in Germany—involves work of investigation leading to results, work devoted to the application of knowledge and the solution of problems. The industries in Germany are wise in choosing for their employees and directors those who have passed through the office of *Privatdocent* and have had, therefore, experience in the training and management of men. That men may become successful without this very extended and profound training is manifest in this country, and is due largely to the men themselves. But even such men would be better equipped for their work by the training provided by the undergraduate and post-graduate schools and, though frequently compelled by their necessities to enter upon their life work without it, they would save much labor and loss of time to have had it. Many of those who, even with limited training in the schools, have been reasonably successful in the industries, and in their life work in this country, have a right to speak feelingly and affirmatively upon this point.

May young men be overtrained? Surely—in the laboratories and in the class-room, as in the gymnasium and on the athletic field; and they may be weakened, from a practical standpoint, by their training. Yet even these are often carried by their enthusiasm to eminent success. "Fools rush in where angels fear to tread," applies equally well in the world of science and industry as elsewhere, and the struggle to get out after the rush in has produced some of the best results the world has seen, though the influence and the method may not always have been recognized or acknowledged. Each one who has had experience may furnish evidence of this fact. Effort to correct error of one's own making often leads to splendid results. "Necessity is the mother of invention," and the needs of a man in deep trouble make him devise means which otherwise remain dormant and without utilization. Yet errors should be avoided, and the more thorough training should lead to this.

Will the institutions meet this demand for better trained men? Will the new courses necessary to it be established? Of this there can scarcely be a doubt. The institutions are looking for the sign and will respond to it when it is plain. But what of the industries? Will the leaders make the sign prominent and clear? Will they do their share? Do they know what their share is? And do they appreciate their responsibility?

First, the institutions must know what is needed and the knowledge can be acquired only by close relations with the industries. Teachers should have ready access to the industries and their work for themselves and their students. Problems should be submitted for the research laboratories and needed means and materials provided. Such cooperation must certainly lead to important progress, not only in the industries, but in the related sciences, and progress under such circumstances is inevitable. May the influences which control have free course, and be not only justified but glorified.

WM. MCMURTRIE

## *THE PROGRAM OF THE INTERNATIONAL COMMISSION ON THE TEACHING OF MATHEMATICS*[1]

"IF we could first know where we are and whither we are tending, we could better judge what to do and how to do it." These words of Lincoln, like the words of many another genius, adapt themselves to divers situations. This statement epitomizes what the International Commission on the Teaching of Mathematics is to do. The first purpose of this body is to investigate the actual state of the teaching of mathematics in the various countries, and the second purpose is to discover the tendencies of the changes effected during the last two decades. Both of these investigations are to be made with a view to determining "what to do and how to do it." In the language of the central committee the aim of the commission is to suggest those general principles which should guide the teacher rather than to provide programs which should be adapted at the same time to the schools of all countries.

To Professor David Eugene Smith, of Columbia University, belongs the credit of having first suggested the formation of such a commission in the French mathematical journal, *L'Enseignement Mathematique,* in 1905 and again at the International Congress of Mathematicians at Rome in April, 1908. This congress authorized a committee consisting of Professor Felix Klein, Göttingen, Germany; Professor Sir George Greenhill, London, and Profesor H. Fehr, Geneva, Switzerland, to form an international commission. Those countries which have been represented at certainly two of the international congresses of mathematicians, with an average of at least two members, are entitled to representation on the active membership of the commission, while other countries are invited to be represented by associate members. The national delegations are urged to affiliate with themselves national subcommissions, comprising representatives of the various stages of the teaching of mathematics in the general schools and in the technical and professional schools.

General direction is lodged in the original committee of three, Klein, Greenhill and Fehr. The official organ is *L'Enseignement Mathematique,* and the official languages are English, French, German and Italian.

The whole field of mathematical instruction, from the earliest primary work to the higher mathematics of the universities, is to be included in the investigation. A large place will be given to applied mathematics for technical and professional schools.

The work of the commission will be based upon the reports of the delegations, which are to be made out with the aid of the national subcommissions in conformity with the general plan fixed by the central committee of three. In the first part of these reports will be given a view of the actual scheme of studies, the corresponding examinations, the methods of teaching and the preparation of the teaching body. In the second part will be presented the actual tendencies of the instruction.

The aim of the mathematical instruction in the different types of schools—primary, secondary, trade schools, normal schools and teachers' colleges, and colleges and universities—will be discussed. Should the aim of the instruction be the development of the mathematical faculties, or logical reasoning, or

[1] The complete Preliminary Report appeared in *L'Enseignement Mathematique,* and a translation by the author (of this article) in *School Science and Mathematics,* February, 1909.